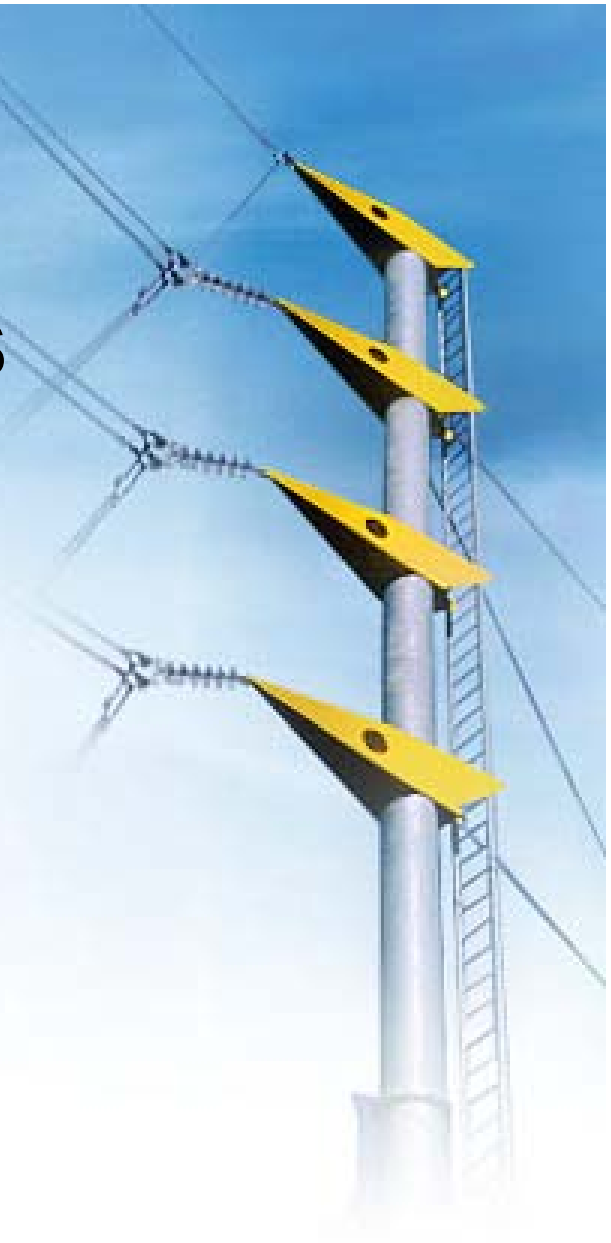
The effects of substation failures on power system reliability



Sintef Workshop "Increased Utilisation of the Nordic Power Transmisions System"

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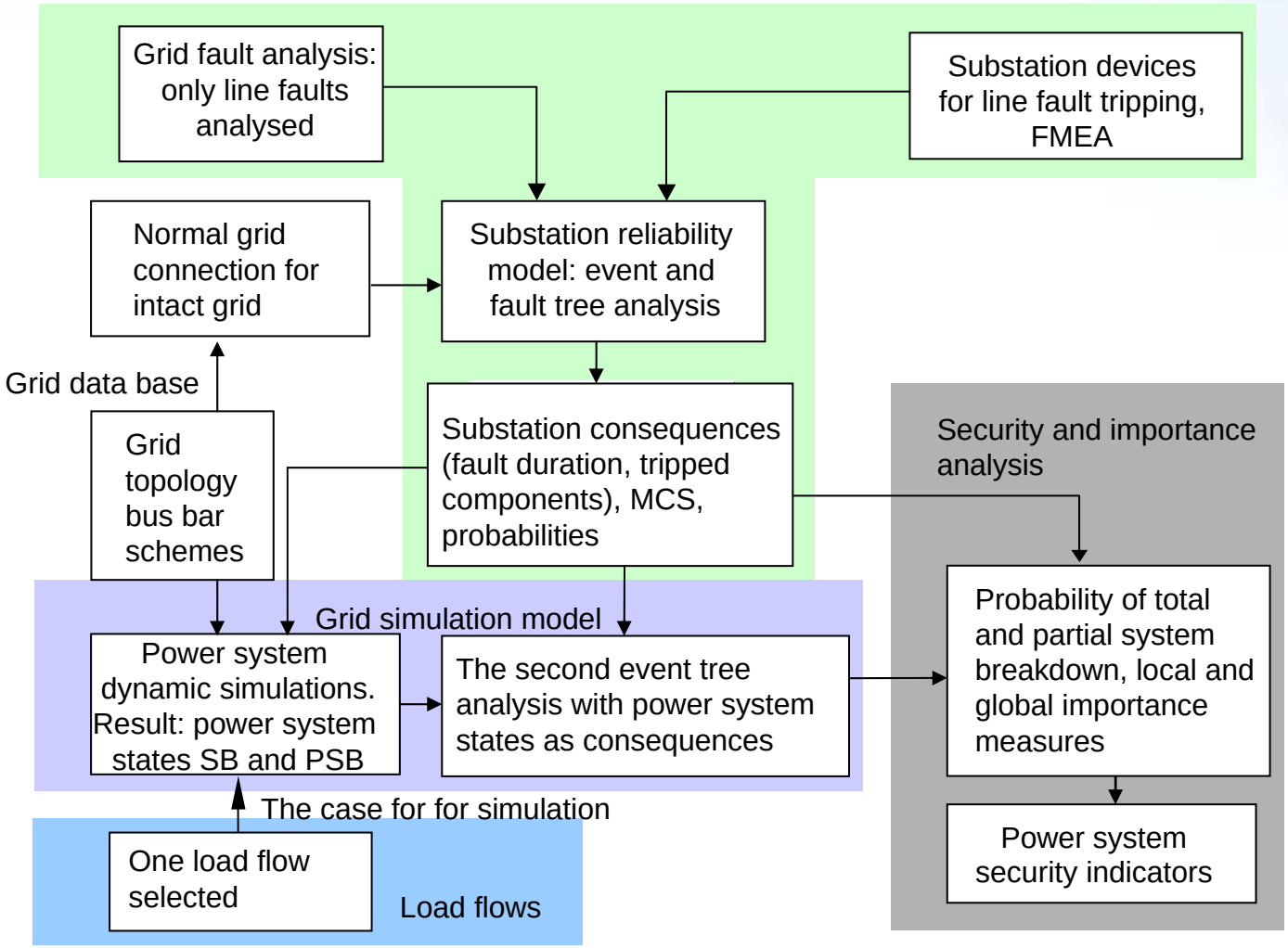
Background

- Transmission system operator (TSO) has the responsibility for the grid security
- Most efficient contributions to the system security with probabilistic methods
- There was no substation model in the grid security analysis. However, the failing of post fault operations at the substation can create problems to the system
- Importance analysis of substation components requires a grid level analysis. The power system state needs to be considered rather than the outage of a single component

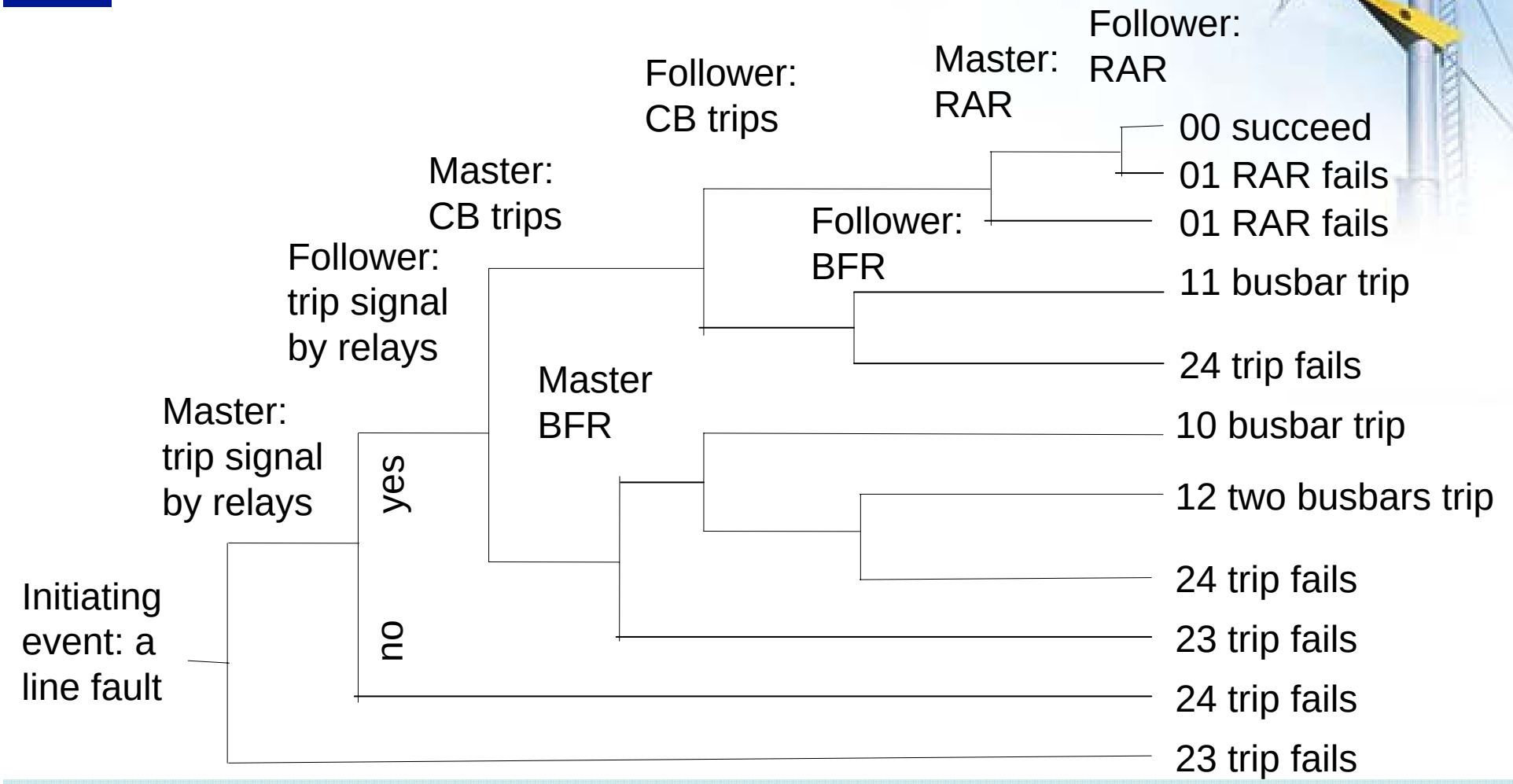
Objectives of the research project were:

- **A probabilistic method for transmission grid reliability analysis that could help to use the always limited resources in the best possible way**
- **To see if the Probabilistic Safety Assessment (PSA) would be applicable for power system security estimation**
- **An estimate of the Finnish 400 kV grid reliability**
- **Compare different busbar schemes and sub-station components as regards the reliability**

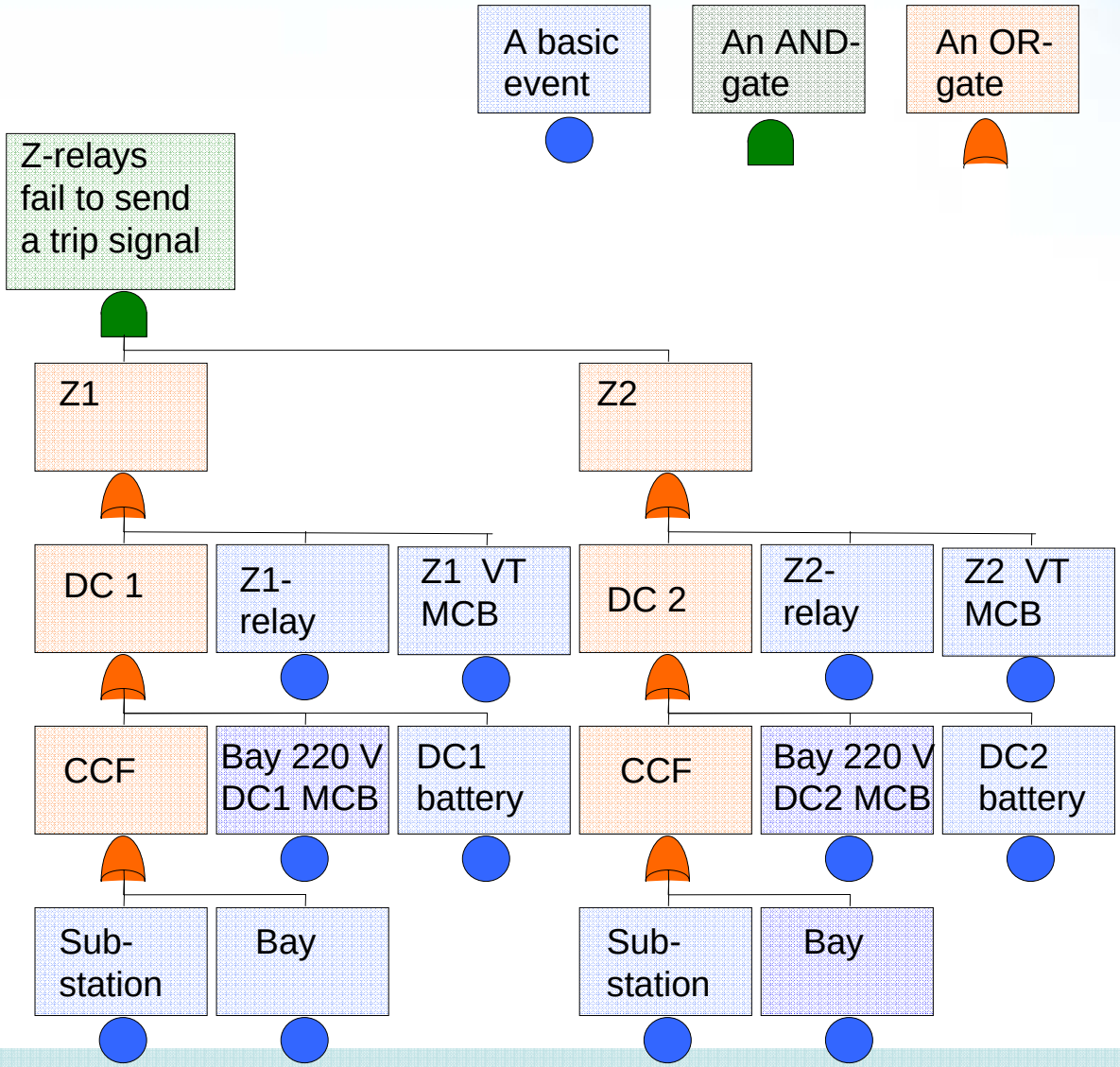
Reliability block diagram



Event tree

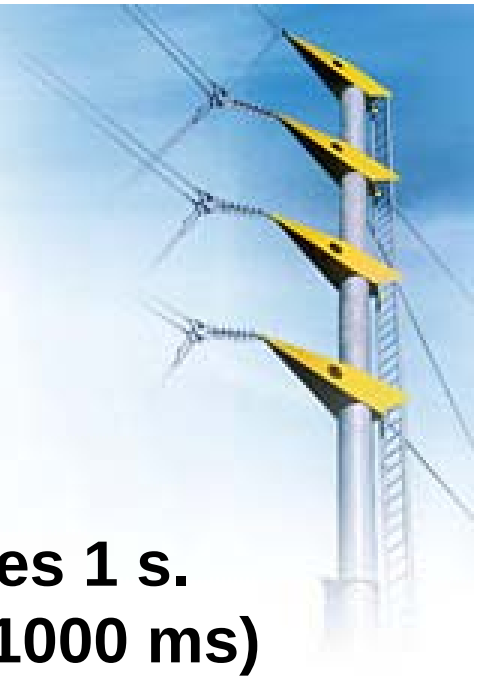

Initiating event: a line fault
Master: trip signal by relays
yes
no
Follower: trip signal by relays
Master: CB trips
Master BFR
Follower: CB trips
Follower: BFR
Master: RAR
Follower: RAR
00 succeed
01 RAR fails
01 RAR fails
11 busbar trip
24 trip fails
10 busbar trip
12 two busbars trip
24 trip fails
23 trip fails
24 trip fails
23 trip fails

Fault tree



Input data for basic events were received from FMEA

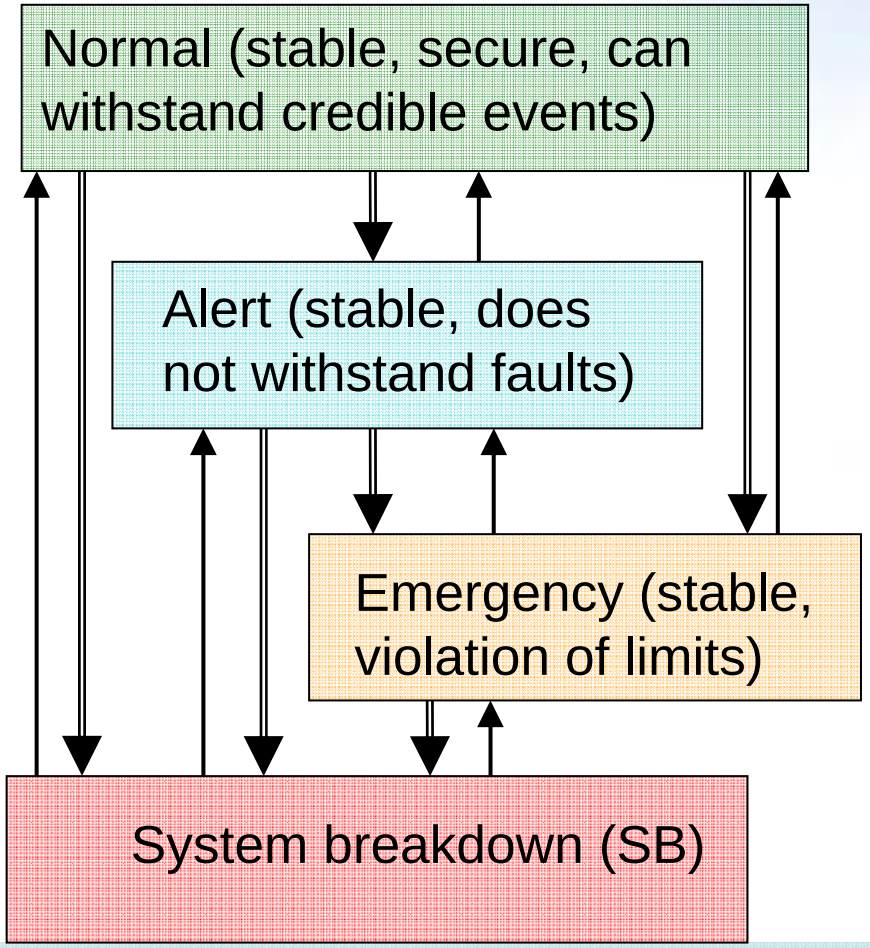
Dynamic simulations



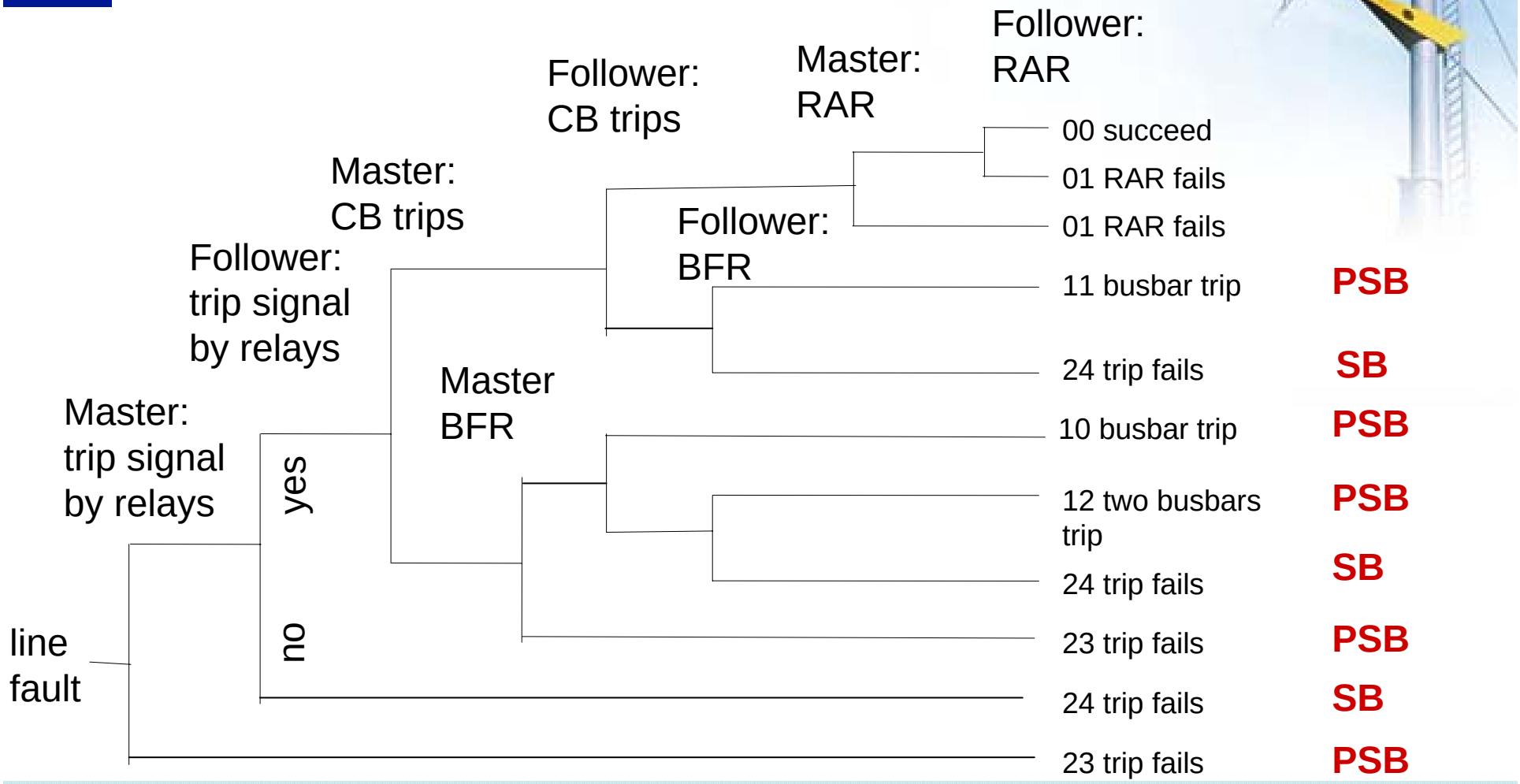
- PSS/E software, one load flow used
- 20 seconds simulation time. This includes 1 s. pre-fault and the fault duration (100 ms - 1000 ms)
- Voltage, angle, frequency stability and over-loadings were checked in the post-fault state
- About 1400 different simulations made (39 lines, 25 - 55 substation consequences / line)
- Post fault state of the system classified
- Remote back-up operation checked separately

Classification of power system states

Partial system breakdown (PSB)
A special 'alert'-case,
in which extra generators
or HVDC links
are disconnected due to
extended fault duration



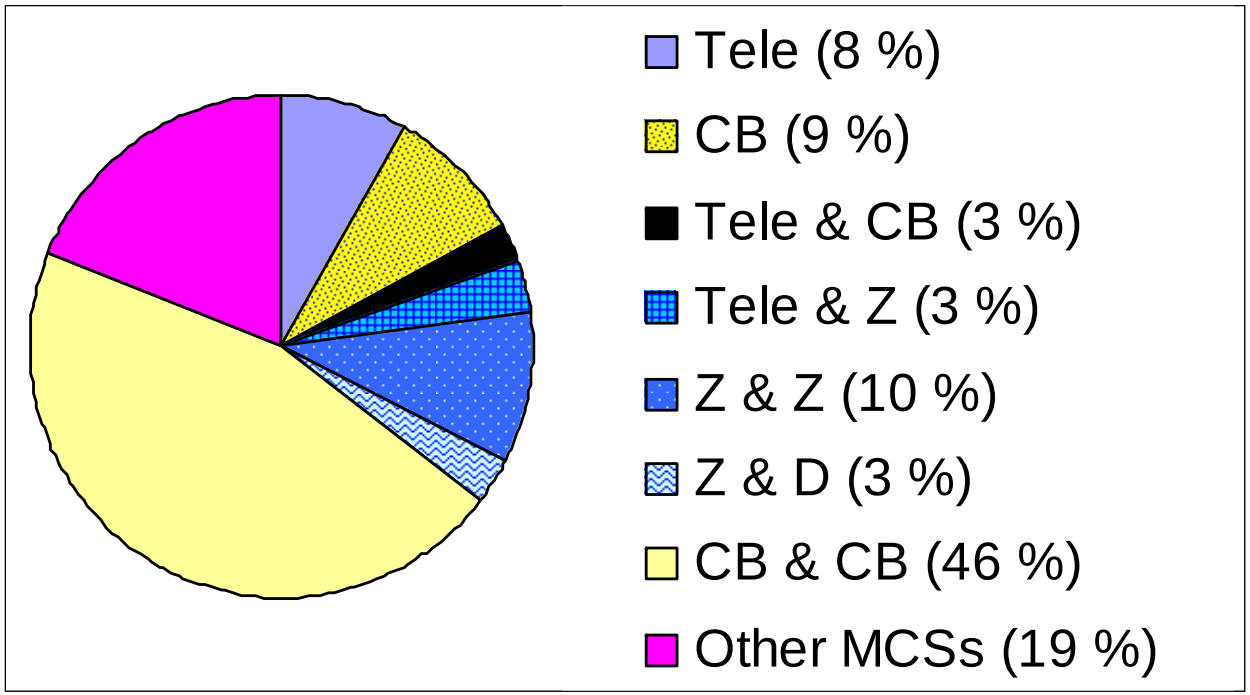
The second analysis of the event trees



Results

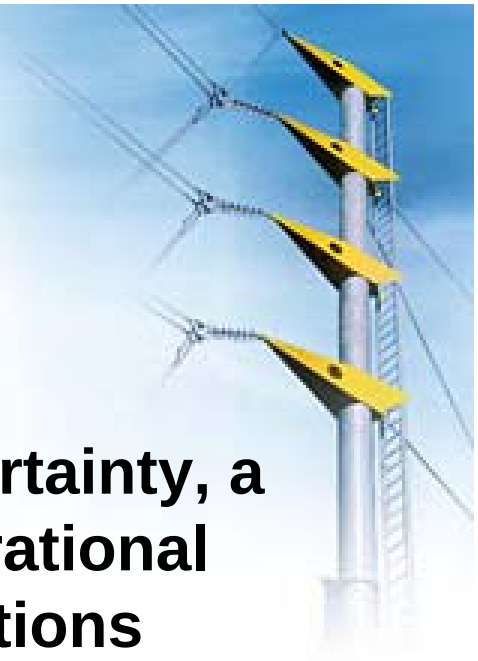
- **Quantitative results of substation components (minimal cut sets, frequency, importance)**
- **Series of events that lead to a system break-down after line faults were recognised (combinations of certain line faults and sub-station device failures)**
- **Importance measures for the substation equipment made as regards to system break-down -> recommendations for the maintenance and for grid planning**
- **In general: circuit breakers are more critical than the protection devices**

Minimal cut sets for system breakdown



Tele = Telecommunication channel
CB = Circuit Breaker
Z = Distance relay
D = Differential relay

Interpretation of the results



- **Probability indicates the degree of uncertainty, a result like 'blackout once in 9 years' is a rational belief based on certain case and assumptions**
- **The model connects the evidence of the device reliability to the grid breakdown frequency**
- **I have modelled what we know about the system**

Thank you for your attention

Thesis " A method for the probabilistic security analysis of transmission grids" in the web:

http://lib.tkk.fi/Diss/

select: 2005

then select Pottonen Liisa